



INEEL Laser Ultrasonic Camera

Researchers at the Idaho National Engineering & Environmental Laboratory (INEEL) have developed a unique and versatile new method for detection of ultrasonic motion at surfaces. This method directly images, *without the need for scanning*, the surface distribution of subnanometer motions at frequencies from Hz to GHz.

Ultrasonic waves form a useful nondestructive evaluation (NDE) probe for determining physical and mechanical properties of materials and parts. The reason for this is that ultrasonic waves or "sound" can be generated in all forms of matter: liquids, solids and gases and exhibit information about the material in which they travel. Measurement of the characteristics of ultrasonic wave motion, such as wave speed, attenuation and the presence of scattered waves from microstructural features or flaws are used to perform NDE for quality control. Laser ultrasonics refers to the process whereby lasers are used for both generation and detection of ultrasonic waves in materials, thereby providing a noncontacting method for performing ultrasonic NDE. The current state of the art utilizes a pulsed laser for ultrasonic generation through the process of thermoelastic expansion or weak ablation. The method of detection involves interferometry of the Michelson, Fabry-Perot, and Photorefractive (adaptive) types. Commercially available systems utilize these interferometric methods and provide a "point and shoot" single point measurement capability. In order to perform measurements over a large surface, the laser generation and detection spots must be *scanned* in a raster fashion over the area recording ultrasonic signals at each location.

In contrast, the *INEEL Laser Ultrasonic Camera* employs a photorefractive (adaptive) approach to interferometry to provide full-field real-time images of ultrasonic motion over large areas. The basic information to be measured, the ultrasonic motion of the surface, is impressed onto the phase of the detection laser beam just as with the other passive methods. The entire optical image of the vibrating surface is formed inside the photorefractive material where it undergoes real time processing due to the dynamics of the photorefractive process. Nonlinear optical mechanisms within the photorefractive recording material are utilized to produce an output image that is a "picture" of the vibrating surface. The net effect is that interferometric detection is accomplished over the entire vibrating surface all at once without scanning, producing an output that can be viewed directly with the eye or with a television camera. No additional electronic or computational processing is required! By eliminating the need for scanning over large areas or complex parts, the inspection process is greatly speeded up.

Laser ultrasonic methods provide noncontacting approaches that are desired for field applications, such as for remote measurements and in-situ manufacturing process monitoring. An example concerns the anisotropic properties of sheet materials that can be determined by measuring the propagation of elastic waves, known as Lamb waves, in different directions. The *INEEL Laser Ultrasonic Camera* produces a real-time image of propagating Lamb wave modes in all directions along the sheet simultaneously. The resultant image provides a direct quantitative determination of the phase velocity (which depends on the material microstructure, density, and elastic properties) in all directions immediately, showing plate anisotropy in the plane. Ultrasonic motion of all types in most materials can be imaged and measured with this new approach.

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